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ABSTRACT

This study focuses on possible factors which contributed to the low mathematics scores achieved by Florida's 11th graders on the 1977 Functional Literacy Test. The authors developed preliminary hypotheses to explain the low scores based upon professional conjecture, analyses of test items, and examination of item data from the October 1977 test administration. Results from this pilot study on a small sample of north Florida high school students provided tentative findings which are highly relevant to the analysis of student difficulties in solving math application problems. Also included in the report are considerations for test construction, recommendations for curriculum improvement, and ideas for remedial math programs. (Author/CM)

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FUNCTIONAL LITERACY IN MATHEMATICS

AUGUST 1978

TM 830 148

FUNCTIONAL LITERACY IN MATHEMATICS

BY

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Under Contract to: Assessment Section
Bureau of Program Support Services
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1978

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In addition to the principal investigators, members of the project were Paul Scott, graduate student in Mathematics Education and former high school mathematics teacher in Woodbridge, Virginia; Bill Cecil, graduate student in mathematics education and high school teacher in Naples, Florida; Joan Gallini and David Logsdon, graduate students in Educational Research, Development, and Foundations at Florida State University.

FUNCTIONAL LITERACY IN MATHEMATICS

by

John R. Hills

and

Tom Denmark

The Florida Legislature in 1976 enacted a revised Educational Accountability Act which requires that in order to obtain a high-school diploma starting with the 1978-79 school year a student must demonstrate functional literacy. The procedure for demonstrating such competence is the passing of a test designed by the Student Assessment Section of the State Department of Education. The initial form of that test was administered to about 120,000 eleventh graders in October, 1977 with results anticipated by the educators involved in the activities of student assessment, but apparently quite surprising to the people of the State. While 92% of the students passed the section of the test dealing with communications skills, only 64% passed the section concerned with use of mathematics in solving everyday problems. Passing scores on both of these sections are necessary to meet the requirement of being sufficiently competent in these applications of basic skills to be certified with a high-school diploma. The over-all

passing rate on both sets of skills was markedly lower for minority students, particularly black youth, than for whites, with their passing rate on the mathematics skills being only 23%.

Such levels of performance on mathematics skills contrasted to communications skills causes one to ask what is happening. A number of possibilities exist. For example, the mathematics questions could have been made harder than the communications items. If that increased difficulty is spurious due to some obtuseness in the items rather than to the nature of the skill applications, then suggestions for sounder test construction would be in order and welcome. If the mathematics items are harder simply because students have not learned mathematics as well in relationship to what the people of the State expect (as interpreted by committees of teachers, curriculum experts, administrators, and lay citizens who specified the objectives which eleventh graders should be able to perform), then suggestions for revisions in the curriculum and for remediation of weaknesses would be appropriate. Therefore this modest pilot investigation was instituted in order to explore the low mathematics scores, with special attention to whatever can be found that might account for the low performance of minorities.

Objective of the Study

The objective of this study, then, was to develop

tentative recommendations for remediation, for curriculum, and for test construction of the Functional Literacy Test mathematics section from information collected in a brief period of time, from a limited number of students available during the Summer of 1978.

Development of Initial Hypotheses

Anyone who ventures to consider what might be happening to produce the differences in performance revealed by the Functional Literacy Test scores and who has some quantitative background and experience with schools, can start out with conjectures. We had several based on our experience without benefit of even seeing the Literacy Test items or any data from them. We can list at least five:

1. The difficulty lies in the nature of the test items in that they are "word problems," and students have difficulty reading the problems. So if students' reading skills were improved, their skill in solving everyday mathematics problems would likewise improve.

2. The difficulty is that the students lack the basic computational skills. If they can't do simple arithmetic problems, such as multiplication and division, operating with fractions and mixed numbers, and using decimal numbers, they have difficulty with applications of those procedures. Thus if students acquired proficiency with the prerequisite computational skills, their performances on Functional

Literacy Test items would show improvement.

3. The difficulty is not that the students can't read the problems or do the arithmetic, but it is a matter of not knowing how to get started--how to set up the problem--how to figure out a sequence of steps which would lead to the solution of the problem. If this is the case, then what is needed is instruction and practice with problem solving techniques.

4. The reason for the low performance level is that the problems are not relevant for students. If the students do not find them interesting, they are not motivated to solve them. Therefore, the solution for increasing Literacy Test quantitative scores is to use more relevant topics--doughnuts instead of ounces of breakfast food, square yards of carpet for their room or clubhouse instead of tile for an auditorium floor, etc.

5. Finally, one idea that occurred to us was that the difficulty may come from the wording of the items. Thus, problems would be easier for students if the question came first (or last) in the stem, instead of the reverse, so that the student's attention was focused on the right place at the right time.

Along with the conjectures that we brought with us into the study, we examined the actual items on the Functional Literacy Test and also the item analysis data for those

items. From simply examining the items it seemed that there were several factors which might have increased the difficulty of the test. Many of the items were associated with art work. Sometimes it appeared that the art work was not necessary for solution of the problem. In such cases the art work was an attempt to make the problems more realistic and interesting, not to provide data essential to the solution of the problem. However, in other items the information needed for the problem solution was presented in the art work. On such occasions, the items seemed to be unusually difficult, which led to the hypothesis that after a series of items in which art work did not matter, to make it essential increased the difficulty of the item. Another related conjecture is that simply making the student look in two places, the item stem and the art work, made the item more difficult. Also in some cases the art work posed a different problem from that posed in the item stem. While this situation occurs in everyday life, e.g., the advertisement suggests you find the sale price but you really need to know how much you save, it may be that by introducing this much reality in test items, the scope of the present mathematics curriculum has been extended.

Many of the items on the Literacy Test required the student to obtain information from tables, such as tables of conversions from cups to pints and to gallons. One would expect that some students would overlook the conversion tables

or not know how to use them and thus have more difficulty with those items.

It appeared that in some items, more information was supplied in the art work or tables than was needed for a solution. The student had to choose the information that was useful. We hypothesized that such items would be more difficult.

Some items had sets of options such that a test wise student could use approximate values to those given in the problem and thereby eliminate all but the correct answer. For example, if the item required multiplication of 37.325 by 21.110 and no option were greater than 700 except 787.931, the clever student does not need to do the multiplication to find the answer. He can simply multiply 20 by 35 in his head, realize the answer must be greater than 700, and select the only possible choice, 787.931.

For other items, all the distractors were so far from the correct answer that the clever student could analyze the problem situation and determine the correct answer without working the problem. For example, in a problem which requires the determination of the total cost of an object, including sales tax, if all but one of the response options are less than the purchase price, the observant student could select the correct answer without doing any computation. We hypothesized, then, that such items might

be easy, and that some students would be found who used such techniques and did well on the test by that means.

Finally, it was clear that some problems required only one step for their solution, while others required as many as five or six steps, depending on how one solved them. We guessed that multi-step problems would be more difficult.

These preliminary analyses of the test items led, then, to the following hypotheses:

1. Unnecessary art work results in failure to recognize that necessary information may only be present in the art work.

2. Items in which the student must look both at the item stem and at the art work to get necessary information are more difficult.

3. Items which utilize data presented in a table of conversions are more difficult.

4. Students fail to use approximations to estimate results and eliminate incorrect distractors.

5. Students fail to eliminate wildly inappropriate distractors.

6. Problems with several steps are more difficult than one-step problems.

As a result of examining item data, we were unable to discern any kind of item that was characteristically more difficult for blacks than whites. Most items tended to be

more difficult for blacks, and the occasional item which failed to follow the general trend seemed inexplicable. No rationale we could generate would account for the item's behavior or give any clue as to a kind of item that would generally be biased among the items on the test. (For all practical purposes, one might conclude that the item writers and test developers had produced tests with no detectable item bias.)

However, some kinds of items were harder for everyone than other kinds of items. The particularly difficult skills (fewer than 54% of the examinees passed these skills) were comparative shopping, interest, area, weight, and elapsed time.

One particular operation seemed to cause difficulty. That was division.

One particular kind of problem also was noticeable. If a conversion of scale was necessary, but the conversion was not supplied, e.g., square feet to square yards, very few students could do the problem.

Examination of item data from the October 1977 Functional Literacy Test administration yielded, then, these hypotheses:.

1. No detectable kind of item was biased for or against minorities.

2. Some kinds of items were particularly hard--those

on comparative shopping, interest, elapsed time, area, and weight.

3. Problems which require the student to divide one number by another are difficult.

4. Supplying all conversions, such as dividing by 9 to convert square feet to square yards, would make problems of that kind easier.

Three Phase Approach

After consideration of the factors discussed above, the project team decided to follow a three-phase approach to eliminating hypotheses and formulating new ones. First, we would assemble sets of items on these five difficult topics and administer the items to individual students in an interview situation. During the interview we would see if they could do the problem, see if they could read the problem aloud, see if they could explain the problem in their own words and gestures, try to find out how they worked the problem, see if they worked the problem mentally or used pencil and paper, and see what else we could discover. We started out using an experienced interviewer who has years of work in remedial mathematics and the teaching of mathematics teachers. He interviewed individual students while another member of the team watched to learn the technique and to assist in observing. Ten individual students were interviewed in this way, each responding to about six

problems, of various sorts. The interviewer chose items from a large set he had created for this purpose, often inserting special contrasts to see what would happen. Each interview took about 30 minutes. At the end of this phase, the team gathered to discuss what had been observed, which hypotheses survived, which should be discarded, and which new ones developed.

This produced the material for phase two which also consisted of personal interviews with students, but this time with carefully prepared sets of items, with six interviewers each interviewing three students with the same set of items. Again, each interview took about thirty minutes. The set of items each interviewer used covered all five areas, but with more than one item in some areas in which particular contrasts were of interest. After this interviewing was concluded, the team members met and discussed everything they had observed and that could be derived from the students' written work and the interviewers' notes. Again, hypotheses were kept, discarded, and generated.

The third phase attempted to evaluate as many of the remaining hypotheses as possible by means of a written test given to about eighty students. Two test forms were used, with many items in common but also many items not shared. Each form was designed to provide information about several hypotheses. All items were open-ended, and space was made available

for the student to show his work. However, no student was questioned about what he had done or how. These data were tabulated in several different ways, and one member of the team went over each student's work to try to determine whether useful patterns of errors could be discerned. The team members again met, discussed everything they had done, and generated the final set of hypotheses and recommendations for test construction, curriculum design, and remediation.

Subjects

The subjects used in this study were not chosen to represent any population. They were subjects who were convenient during the life of the project, one summer session. Nearly all of them had failed the Functional Literacy Test or were in classes preparing for it. However, some who took the written test were in advanced mathematics classes. Some were from large-city high schools. Others were from a small town high school. All were located in the panhandle of north Florida. The actual pattern of use of subjects, including the number in each group appears in Table 1.

Results

The results of the research will be presented phase by phase with an over-all summary and recommendations. For each phase, some additional details on the data collection

Table 1

Subjects

		Rural Phases			Urban Phases			
		I	II	III	I	II	III	Total
Func. Lit Test Prep.	Male	0	7	0	3	0	18	28
	Female	0	11	0	7	0	21	39
Advanced Mathematics	Male	0	0	0	0	0	21	21
	Female	0	0	0	0	0	17	17
	Total	0	18	0	10	0	77	105

will be presented.

Phase I

This phase was a combination of exploration and training of interviewers. While no elaborate recording form was used, the scratch paper used by the students was collected, and the trainee kept notes of student behavior which might be related to hypotheses under question or to future hypotheses. Ten students were interviewed in three sessions occurring about three days apart. All students came from the same class of students being groomed for the Functional Literacy Test in an urban high school's summer session. During this phase some hypotheses were rejected as too unlikely to be worth further pursuit. Some were cast into doubt. Others were strengthened or generated. We will list them in turn.

Hypotheses Rejected:

1. Relevance of the item is important. We could detect no influence on student behavior of item relevancy. They seemed equally competent at comparison shopping on paint as on cola, for example.

2. Location of the question at the beginning or end of the stem is important. We could detect no influence of this factor.

Hypotheses Cast Into Doubt:

1. Students cannot read the problem. They seemed able to read all the words with inflection as though they under-

stood the questions. Only rarely did a word seem to give any problem, and when asked if any words were troublesome, the inevitable response was negative. We still wondered whether they merely could read the words but not comprehend, so we decided to explore this further in the cloze format which better reflects comprehension.

2. Students cannot use tables to look up necessary information. We provided them with tables which they seemed to use effectively with no problem. That is, they could look up the conversion from cups to pints with apparent ease. They might not be able to use the conversion, but they could point to it, read it, and say it, without assistance.

3. Students profit from looking at the alternative responses to multiple choice questions, using them to decide how to solve the problem. We found no evidence of this at all. Not a single student made any comment which indicated that clues were found among the alternatives. Even if their answer was wrong, they usually stopped working on the problem after finding it present. If they did not find their answer, some worked longer trying to find an answer that was present, while others merely ignored the fact that their answer was not among the choices. Use of all of the information available is a good strategy in test taking as well as in life. Apparently students are not learning this strategy in approaching mathematics problems.

4. Students would use approximations and would estimate what the correct answer should be as a check on their computations. We found only rare instances of these kinds of behavior. Apparently students are not learning that "ballpark" estimates are excellent checks on detailed computations, and that it is helpful to round off mixed numbers or decimals to the nearest integer or factor of ten, one hundred, etc., and then to multiply, divide, add, or subtract with those numbers to determine about what size the desired result should be. In multiple-choice problems, that procedure often eliminates all but one answer, and in real life it often keeps one from making a gross error.

5. Students are unable to do the arithmetic involved in the problems. In several cases we ascertained that a student could not solve a problem, but when presented with the arithmetic involved could readily do that part of the problem. It appeared that the arithmetic was sufficiently simple that it was not the source of difficulty in functional literacy problems.

New and Strengthened Hypotheses:

1. Students just can't formulate the problem. This was one of our initial hypotheses, even before we examined any data or items. It seemed even stronger after Phase I. Though they could read the words of the problem, and use gestures to explain what should be done, such as divide

several pounds of meat into patties, they did not know how to start to determine how much each patty would weigh.

2. Students can't set up the arithmetic. Sometimes, as in comparison shopping, they seemed to know that something must be divided by something else to get unit cost, but they were not sure what. They tended to set things up so large numbers get divided by small numbers, whether that was the procedure required by the problem or not.

3. Students make careless errors. We noticed during Phase I that many careless errors were made, and students seemed not to have the idea of checking their work by using a different method or a backward solution.

4. Students do not have quantitative concepts, intuitions, or "feel" about quantities. They often work by rote, doing "what my teacher taught me to do on this kind of problem" without any understanding. For example, one student solved the problem of dividing 8 pounds of hamburger into 32 patties, finding that each patty would weigh 256 pounds. Even though we pointed out that none of the interview team members weighed as much as 256 pounds, she stuck to her anwwer because her teacher told her that "each" means to multiply.

5. Students apparently learn certain key words, such as each, which tell them what to do without their having to think. When the key word is used in a different sense or context, it leads to error.

6. Problems involving conversions are difficult. Phase I data strengthened this hypothesis which came from the initial examination of the items and data.

7. Conversions which involve division are especially difficult, another hypothesis from examination of item data that was supported in Phase I.

8. Multiple-step problems are harder, another strengthened hypothesis initially generated after looking at item data.

9. Items in comparison shopping which involve "continuous" substances, like ounces of cereal, are more difficult than those which involve discrete substances, like numbers of doughnuts. In at least one case, the interviewer happened to try a student on a doughnut problem after failure with cereal, and the student seemed to have no difficulty, which led us to wonder if the discrete nature of the doughnuts was a clue.

10. Use of models, such as a clock face for telling time and working out elapsed time, might assist students. Again, one student seemed able to solve problems about how long lunch period was once a clock on the wall was called to her attention, but she could not effectively even think about the problem until then.

Phase II

In Phase II, each student received one or more problems in each area, with some contrasts built in, such as one comparison shopping problem in which a large number must be divided by a small one and a similar item in which a small number must be divided by a large one in order to get unit cost. There were six different "forms," each given to three students, with six students responding to each item. The pattern is displayed in Table 2. The items are listed by content area and item number in Table 3. In some cells of Table 2 there are two item numbers. These pairs of items provide specific contrasts in which we wanted to be sure that the difference in performance was not a matter of different examinees taking the different items. More such contrasts could have been used in a more extensive study, but these were the ones we could fit into our practical limitations. The reader can examine these contrasts by study of the items involved as they appear in Table 3.

The interviewers provided each student with a sheet of paper for each item, giving him the item and a lot of blank space for scratch work. The interviewer had a similar sheet of paper with the item and space to fill out various comments about the student's approach and to record that certain steps were taken, such as asking the student to read the question aloud. An example of such a protocol sheet appears in

Table 2

Item Numbers in Various Test Forms, Phase II

Content	Forms*						No.
	A	B	C	D	E	F	
Comparative Shopping (C)	1,2	4,6	2,5	5,6	1,3	3,4	6
Elapsed Time (E)	4	1,2	3	2	1,3	4	4
Interest (I)	2	1	1,2	4	3,4	3	4
Area (A)	1	2,3	4	3	4	1,2	4
Weight (W)	3,4	3	2	1,2	1	4	4
Number of Problems	7	8	7	7	8	7	22

* Each form was given to three students in individual interviews.

Table 2

Item Numbers in Various Test Forms, Phase II

Content	Forms* A	B	C	D	E	F	No.
Comparative Shopping (C)	1,2	4,6	2,5	5,6	1,3	3,4	6
Elapsed Time (E)	4	1,2	3	2	1,3	4	4
Interest (I)	2	1	1,2	4	3,4	3	4
Area (A)	1	2,3	4	3	4	1,2	4
Weight (W)	3,4	3	2	1,2	1	4	4
Number of Problems	7	8	7	7	8	7	22

* Each form was given to three students in individual interviews.

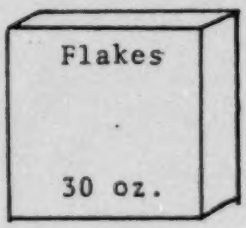
Table 3

List of Items In
Each Content Area, by Number, Phase II

Comparison Shopping

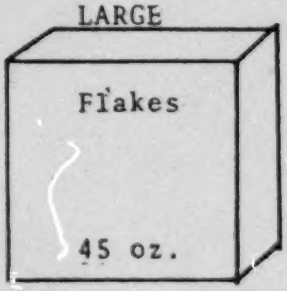
C 1 How do the two boxes of cereal compare in cost for one ounce?

SMALL



70¢

LARGE



99¢

C 2 How do the two bags of doughnuts compare in cost for one doughnut?

SMALL

60¢

LARGE

84¢

C 3 How do the two bottles of cola compare in cost per ounce?

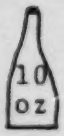
A. The regular size costs more per ounce.

B. The large size costs more per ounce.

C. The cost is the same per ounce.

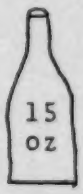
D. There is not enough information to tell.

Regular



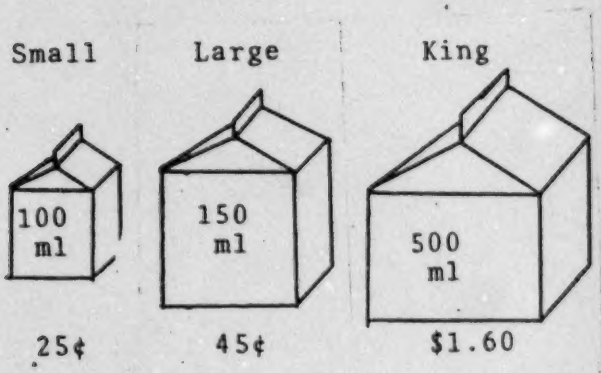
30¢

Large



45¢

C 4 Which carton of juice costs the least per milliliter (ml)?



A. Small

B. Large

C. King

D. They cost the same per ml.

C 5 An 8 ounce bag of candy costs 29¢. A 12 ounce bag of the same candy costs 41¢. How much will be saved on 24 ounces of candy by buying the most economical size bag?

A. $0.05

B. $0.12

C. $0.82

D. $0.87

C 6 For a school party you need to buy 60 paper cups. Which would be a better buy: packages of 10 cups at 23¢ per package or packages of 15 cups at 35¢ each?

Elapsed Time

E 1 About how long did the Jones live in Tallahassee if they moved to Tallahassee in September 1975 and left in February 1978?

E 2 Bill bought a car in December 1976. He sold it in May 1978. About how long did Bill keep the car?

A. 1 yr 5 mos

B. 1 yr 7 mos

C. 2 yrs 5 mos

D. 2 yrs 7 mos

E 3 A movie starts at 7:46 pm and is over at 9:17 pm. How long is the movie?

E 4 First lunch begins at 11:42 and is over at 12:19 How long is the lunch period?

A. 23 min

B. 37 min

C. 1 hr 23 min

D. 1 hr 37 min

Interest

I 1 Bill deposited $500 in a savings account. If the interest rate is 7% per year, how much interest did Bill earn in one year?

A. $7

B. $35

C. $535

D. $3500

I 2 Betty deposited $200 in a savings account. If the account pays interest at a rate of 7% per year, what is the total amount of money in the account after one year?

A. $7

B. $14

C. $214

D. $1600

I 3 Barb has $400 in savings. She changed her account from one bank which pays 5% per year to another bank which pays 6% per year. By making the change she will earn how much more interest in one year?

I 4 Jack borrowed $200 from a Credit Union which charges 12% per year interest on all loans. The terms of the loan are that each month he will pay $20 plus the interest on the unpaid balance. How much interest will he have to pay the first month?

Area

A 1 A bedroom is 10-1/2 feet long and 10 feet wide. How many square feet of floor space are there in the room?

A. 20-1/2

B. 41

C. 100

D. 105

A 2 A school room measures 24 feet by 36 feet. How many square yards of carpet are needed to cover the floor?

A. 96

B. 120

C. 288

D. 864

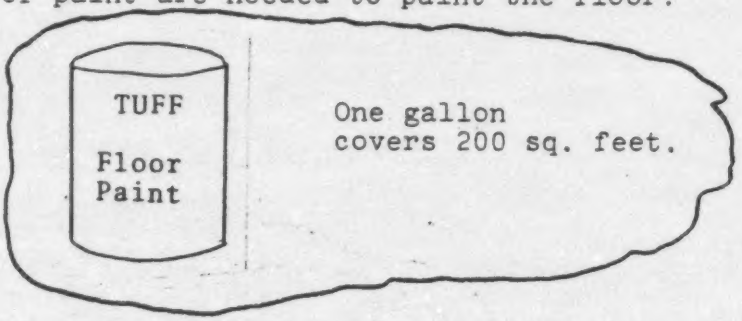
A 3 A floor is 26 feet long and 22 feet wide. How many gallons of paint are needed to paint the floor?

A. 1

B. 2

C. 3

D. 4



A 4 A flat roof is 55 feet long and 24 feet wide. If you plan to nail a metal strip all around the roof, how many feet of stripping do you need to buy?

Weight

W 1 A kilogram of ground beef is used to make 4 hamburger patties. How much does each patty weigh?

A. 4 grams

B. 25 grams

C. 250 grams

D. 4000 grams

W 2 Eight (8) pounds of hamburger meat are used to make 32 patties. How much does each patty weigh?

W 3 How many pounds of candy are needed to make 24 bags of candy which weigh 8 ounces each?

W 4 How many pounds of ground beef are needed to make 32 patties which weigh 5 ounces each?

Figure 1.

After the interviews were concluded, the research team met and went over the resulting information in a general discussion and an analysis of each hypothesis. The results follow.

Hypotheses Rejected:

1. Students have difficulty reading the problems. We asked the students to read the problems aloud and to indicate to us any words that were difficult. Every student was able to read the problems with relative ease, and only rarely was a word mentioned as difficult. We expected the word "economical" to give the most trouble, but no one had any difficulty with it that we could detect. It seemed clear to us that the students can read the words with proper inflection. If they have problems they are not willing to say so, nor can we detect them. Since both Phase I and Phase II found the same thing, we decided the only remaining question for Phase III was whether they could comprehend what they read well enough to recognize what words made sense in paragraphs which asked these kinds of problems, when presented in the cloze format.

2. Students use information in the distractors to help solve the problems. We did not experience a single case of students eliminating distractors or using the response options to solve the problems. Since we found the same thing in

Figure 1.

Interviewers' Record Sheet for
Item E 4; Phase II

E 4 Name _____

First lunch begins at 11:42 and is over at 12:19. How long is the lunch period?

A. 23 min

B. 37 min

C. 1 hr 23 min

D. 1 hr 37 min

Answer: 37 min _____

Read Aloud: YES NO Difficult words _____

Method: Subtract Count Subtract-Count

Mental Written

Distractors: YES NO _____

Errors:

Phase I, it seems appropriate to reject this hypothesis as very unlikely.

3. Students use approximations and estimates effectively. We found no evidence again that they use these procedures, so at this point we reject the hypothesis instead of merely doubting it.

4. In comparison shopping, continuous products are more difficult to deal with than discrete. In Phase I we generated this idea, but it appeared not to hold up at all, so we were prepared to drop it after Phase II.

Hypotheses Cast Into Doubt:

1. Students are unable to use diagrams and tables of conversions. We generated this hypothesis after looking at the test items, but during Phase II we gave students problems that required table lookup, and we supplied the tables. For the most part, students used the tables effectively, making us think this was not as much of a problem as we had guessed it might be.

2. Students do not understand what is meant by simple interest or elapsed time. It seems that they do know clearly what is meant by elapsed time, i.e., how long is lunch or a movie, or how much older is Ned than Susie, but they do not seem to know how to deal with it if the interval crosses an hour or a year. They know that simple interest implies

multiplying the amount by the interest rate. However, we discovered that in the school in which these interviews were done, interest was currently being studied by our examinees. Furthermore, when we asked them what "interest" was, they could not explain it, and seemed not to know when someone received it as opposed to having to pay it.

New and Strengthened Hypotheses:

1. Splitting information between the stem of an item and a table or diagram makes the item harder. We had thought that requiring lookup of information in a table made problems more difficult, but after the interviewing of Phase II it appeared that the difficulty was not in looking up material in a table or using the table, but instead it occurred when the information needed to solve the problem had to be put together from two or more different locations.

2. Students understand the concept of comparison shopping--that what is being looked for is the best bargain, but they do not know how to convert that idea into arithmetic operations.

3. Students do not understand the concept of area. They do not know what is being sought when one asks the area of a rectangular surface, such as a roof, nor do they know what to do to solve a problem involving the area concept. Apparently

this concept was not learned by the students we encountered.

4. Students can read the problems aloud but still don't understand them. They read each problem aloud to us with few errors, and they rarely mentioned that any word caused difficulty, but they still did not understand what was being asked. When they were asked to draw a picture of the situation involving area, to explain who received interest money, or how to determine how much one would save with a bargain purchase, they were at a loss.

5. Students could solve multi-step problems if the problems were broken down into their separate steps. Particularly in comparison-shopping problems which involve finding the unit cost for several pricings and then comparing them to determine which is least expensive for a certain amount and by how much, it seemed that the students just could not follow through on all of the steps. We thought that if we broke the problem into the separate steps, they could do each step and then put together the final answer. We even thought that it might be possible that if we showed them how to do that one time, they would then be able to use the method.

6. Students could quickly learn to do problems of some kinds if they were led into the solutions by a series of gently-graded steps. For instance, if we gave them elapsed-time problems that started with the very simple and gradually worked up to problems involving elapsed time across 12 o'clock, or across January 1, they would be able to do those problems

which seem more difficult.

7. Key words produce errors when they are used by rote without thought. This hypothesis was formed during Phase I and was supported by our interviews in Phase II. It seems to include a number of words, such as "and" means add, "difference" implies subtract, "each" means multiply, "of" means multiply, and perhaps others. Apparently, some students learn tricks that apply to certain types of problems but not to others, but never learn when the tricks work and when they don't. Sometimes they believe in the trick so strongly that it overwhelms their senses (such as 256-pound hamburger patties), their intuition, or their common sense and experience.

8. Students can do the arithmetic if it is extracted from the problem and set up for them. After Phase I we doubted that students were unable to do the arithmetic. By the end of Phase II we felt that there was strong support for the hypothesis that students could do the arithmetic with little trouble, but could not figure out where to do what arithmetic.

Phase III

For Phase III, two test forms were built, each covering two of the four areas of comparison shopping, elapsed time, area, and interest. In order to conserve testing time, the

topic of weight was deleted at this point. It seemed that most of the problems with dealing with weight were analogous to those of dealing with area, the matter of conversions of scale, especially those involving division, so that little information would be lost by this deletion.

Each form started with the same set of 22 computation items. These were used to evaluate fairly thoroughly our hypothesis that students could do the computations, but that their main trouble was not knowing how to set up the problems. We expected quite a high level of performance on these computation problems. Two kinds of arrangements of problems were used. In the first set, each item was set up for computation, e.g., ten times ten was set up in vertical arrangement as follows:

$$\begin{array}{r} 10 \\ \times\ 10 \\ \hline \end{array}$$

The next set were similar items but set up horizontally using words, using different numbers but of an equal level of difficulty, e.g.

11 times 11 = _____.

We thought that it might turn out that students could do the problems in the computational format, but would be less successful with them in the horizontal form, which might be more nearly parallel to the problems they face when dealing with everyday practical problems. If that was the case, it would have implications for remediation. It would suggest

that to increase success on the mathematics section of the Functional Literacy Test it would be wise to stress remediation of this aspect of the basic arithmetic skills for some students.

The next question on each form was a prototype Functional Literacy Test question in either comparison shopping or elapsed time. In each case, this question was designed to be parallel to the kind of question the student would have been asked on the 1978 version of the test.

After the prototype was presented, a multiple-choice cloze reading test was given. The content was a prototype problem statement followed by a paraphrase of that statement. Six or eight important words were deleted from each paragraph, and four choices for replacement of the word were presented at each point. The student was to choose the word that made the most sense in terms of the rest of the paragraph. If students could do that with reasonable success, it would indicate that they were getting the sense of the problem statement--they were not only reading the words as words, but they were comprehending their meaning in the paragraph and understanding what the paragraph was saying. In our opinion, if students could do that but still had difficulty solving the problems, it was not a matter of lack of reading skill in the sense that reading is taught in a reading class. It might still be a matter of not reading mathematical or quantitative

material well, but that would appear to be a skill taught in mathematics classes rather than general reading classes.

Following the cloze paragraph with its six or eight responses came a series of questions which were designed either to break a multiple-step problem of comparison shopping, interest, or area, down into the individual steps, or else to provide a series of steps of gradually increasing complexity of problems which led the examinee to problems of the level of complexity required in the test for the area of elapsed time. These series of questions were used to help evaluate the hypothesis that students could solve the problems if they were broken down into parts, that they could learn to do similar problems quickly if they once saw the steps, and that the elapsed time problems could easily be taught by means of a graduated series of examples.

After the set of problems above, which we call "step problems" for short, we presented another prototype problem to see if the step problems had been sufficient to teach the procedures for solving these problems. We did not really expect one experience to make much difference, but we decided to give it a chance to appear, and having another prototype problem let us examine the possibility that students might be able to do the prototype problems, but not the intervening step problems, a possibility we thought unlikely.

Finally, a pair of questions was asked to compare performance when a key word that suggests an operation was appropriately used with performance when that word was not used in order to evaluate the hypothesis that students were using key words to guide them about the mathematical operations to use in solving these practical problems. (We did not include uses of key words where they might mislead. The amount of testing time available did not permit us to explore many leads that we would have liked to include.)

In the case of elapsed time, we added two additional questions. We thought it might be the case that all the extra words in elapsed-time practical problems relating them to lunch periods, ages of people, dates, etc. might add to their difficulty, especially if students had been taught to solve such problems by the subtraction algorithm rather than by simple counting on. These two problems simply asked the student to subtract one date from another. In one problem the student had to regroup; in the other he did not. The former problem was stated like this:

Subtract June 1975 from August 1976.

After the comparison-shopping problems in one form, a similar series of problems on area was presented. On the other form, the second set of problems was on interest. The two forms were distributed to alternative students providing

systematic samples which should approximate a random distribution.

Data obtained from this test administration were analyzed in several ways. First, the results for all subjects were tabulated, item by item. For the arithmetic problems, each problem and each kind of right and wrong response were tabled. For the cloze items, the total number correct in each set was counted, and the kinds of errors and error combinations were tabulated. For the other questions, one tabulation showed whether each student got each answer correct, and all students who took a particular form were listed on a single legal-size sheet. Another tabulation - for a large number of the students indicated what kinds of mistakes were being made, with separate tallies for each kind of mistake. Also, scores were generated for each student for the number of the arithmetic problems correct, the number of cloze restorations correctly made, and the number of prototype-like items correct. Means were compared for scores on the first eleven and second eleven arithmetic items, and correlations were computed between the total score on the arithmetic items and the sum over the prototype-like items.

With these tabulations at hand, the project team met for several days and discussed the data, the patterns of individual students, and the subjective evaluations

throughout the project. It reached a set of conclusions. For the convenience of the reader, we will bring together the hypotheses from all the phases of the study. We will also rephrase hypotheses formerly listed in the rejected category so that their negation will now be stated as accepted. This should make it easier to discuss our findings, but it must, of course, be remembered that this was a small pilot study whose findings are all subject to verification by other investigators in other settings.

Hypotheses Accepted (by Phase)

1. Relevance is not important. (Phase I)

2. The location of the question in the problem is not important. (Phase I)

3. Students can read the words. (Phase II)

4. Students can read the paragraphs that ask the problems. (Phase III)

5. Students will not use distractors in working out their solutions to the problems. (Phase II)

6. Students do not use approximations and ballpark estimates effectively in solving problems. (Phase II)

7. Students understand what is meant by elapsed time. (Phase II)

8. Students generally cannot do the arithmetic related especially to multiplication of whole and mixed numbers

(decimals and fractions), division of all kinds, and the ordering of decimals and fractions in terms of their size. (Phase III)

Our section on arithmetic surprised us. We had expected to find students getting all or nearly all of those problems correct, but that did not happen. Apparently part of the trouble in applying basic skills to practical problems of everyday life is that among these students the computational skills have not been learned well. Addition, subtraction, and simple multiplication seem to be understood, but they are still subject to carelessness. The more advanced skills give these students undue trouble. This needs to be remedied.

9. The form of the problem (vertical or horizontal) makes a surprising amount of difference in some kinds of arithmetic. For some kinds of items it apparently made no difference, for others the horizontal format was easier, and for a third group the vertical format resulted in the fewest mistakes. Adding decimals was much easier in the vertical format. Also in multiplying two-digit numbers, 10% fewer got them correct in the horizontal format. On the other hand, 12% more got multiplication of fractions correct in the horizontal format, and 14% more got multiplication with decimals correct in that format. From

these limited data one might suspect that remediation could aid these students by making sure they could go from one format to the other with ease. (Our comparison of means in the two formats was unrevealing, since the two formats balanced out to essentially equal means.)

10. Context in elapsed time problems makes them easier. (Phase III). It turned out that when the context was removed from elapsed time problems the students found them nearly impossible. They could not figure out what was being asked. The students we tested in this phase apparently had not learned the subtraction algorithm for elapsed time, and did not recognize that subtraction was a useful way to proceed.

11. Use of the term "area" instead of asking "how many square feet" in area problems makes little difference. (Phase III) We found the problems equally hard when asked either way. Apparently area simply is not being learned by these students to a useful degree.

12. Supplying the conversion of square feet to square yards in area problems makes no difference in the difficulty of these problems. We had initially developed the hypothesis that students could use this conversion if we supplied it. We got that impression as we looked at the item data from the regular Functional Literacy Test administration. However,

we did not check it very carefully until Phase III. At this point, we actually gave students the conversion in the second part of the step-problem on area, but it did not seem to penetrate. They were unable to use the information effectively, which suggests that the whole idea has not been learned during the regular arithmetic instruction.

Hypothesis Cast Into Doubt and Not Resolved (By phase):

1. Students are unable to use diagrams and tables of conversions (Phases I and II).

Hypothesis Left Untested and Unevaluated:

1. Unnecessary art work, and artwork that was misleading in itself or part of a misleading pattern, made problems more difficult. (Initial hypothesis.) While it would have been interesting to study the influence of the art work, and questions about its role remain to be resolved, we simply were not able to include it in the scope of this project.

New and Strengthened Hypotheses (After Phase III):

1. In elapsed-time problems, if regrouping is necessary considering a subtraction algorithm as the method of solution, students do not know how to proceed.

2. Some students count both the first and last date (month, hour, year, etc.) while others don't. It is not clear that one way is more correct than another, but test questions could be (and probably are) written which call one

answer right and the other wrong.

3. In division, problems that have a divisor larger than the dividend are much more difficult than those in which the divisor is smaller.

4. Students understand what comparison shopping is all about, but they do not know how to proceed in solving problems which involve it. Multiple-step problems are particularly difficult for these students.

5. Some words makes problems much harder, for example, the word "compare" in comparison shopping, and the word "subtract" in elapsed time. Other words do not have this effect, for example, the word "difference" in elapsed time. Some words lead to incorrect operations for some problems, for example, "and" in area problems leads to the use of addition in solving the problems.

Summary of Findings

The phase-by-phase report of results you have seen thus far might be very confusing. At this point let us try to bring together what we think we have learned in this modest pilot effort, and then we will draw conclusions, make recommendations, and suggest where we think the major problem lies.

It seems clear to us that some of our early conjectures about the nature of the problem were too superficial.

Whether the question comes first or last, and whether the topic is relevant to the examinee seem to have little to do with the difficulty of these problems. Art work may influence their difficulty; we do not know. Simple reading, as taught in a reading class, is not the basis of the difficulty. Something goes wrong in the interval between the reading and the setting up of the problem into a series of arithmetic operations. That seems to be a reasoning process, not a reading process. The reasoning involved is so closely tied to the arithmetic that we suspect it should be taught in the mathematics classes.

Some of the problem is a lack of basic arithmetic skills, especially the skills involved in division and in operating in any way with mixed numbers.

Some of the problem may be that students try to shortcut the thought process by finding certain words that tell them what to do without their having to think--words such as "each." Unfortunately, these words sometimes lead to the wrong operation, and a student who leans on them as a crutch is putting his weight on a reed. We think students should be taught not to solve problems that way, but instead to think them through logically.

It seems clear to us that problems become more difficult when they are made more realistic by putting in data that are not needed making the examinee decide what information to

use, and by requiring him to bring information together from different places. If this test is to be one of solving practical problems as they occur in everyday life, then it seems proper to have problems that make these requirements, but students must also be taught to deal with those requirements--taught how to select the necessary information, and that this step is something they are expected to learn to do rather than a step put in just to test them. Notice, we are not suggesting merely requiring use of a table for conversions at this point, since we found that, as far as we could tell, that does not hinder these examinees.

Some of the problem is that, not only do students lack some of the basic skills, but also they have not been encouraged to work carefully. We noted many careless errors in students' work. This could be avoided in some cases if students were encouraged to use approximations of the awkward numbers of real life problems in order to estimate what the answer should be, and in what form, i.e., percent, pound, dollars, etc. If they had such estimates, they might recognize that some of their computations had gone badly wrong, and perhaps they would recompute and get the correct answer.

Apparently students are not familiar with the idea of thinking of a model, such as a clock face or a calendar, as

they try to solve these kinds of problems. When we suggested such a model, it was sometimes surprising how effectively the examinee used it. Perhaps more instruction along those lines would make a real difference in Functional Literacy Test scores.

Finally, students are not able to cope with problems, such as comparison shopping, which involve solving various subproblems in an orderly fashion and then assembling those results so that the over-all problem can be solved. They seem either dismayed by the prospect, or feel that not enough information has been given, since they are expected to calculate some of it for themselves.

As we tried to put all the parts of the puzzle together, it seemed to us that students simply were not learning adequately how to deal with practical problems by translating the wording of the problem situation into an orderly sequence of mathematical operations. There are a number of steps in that process, and some kinds of problems can be solved in several different ways. This depth of understanding of the application of basic skills is not being reached by these students--and that seems to be the heart of the matter. Our simple approaches at quickie remediation did not provide the help needed, though they might be useful in longer instructional sequences. This part of practical application

of basic arithmetic skills is not to be learned overnight by the students with whom we were working.

Recommendations for Test Construction

In the course of our interviews and testing, we became aware of several considerations that should be kept in mind during test development and item writing. First, in comparison-shopping items students may be able to grasp the meaning of a question such as which is more economical, or which is the best buy, but they do not know what is meant when they are simply asked to compare. Unless there is some significant reason to ask the question in that way, we would suggest that students not be asked simply to compare two possible purchases.

Second, in elapsed time problems there are differences of opinion as to how to deal with problems when specific dates are not given, e.g., September 1977 to December 1977. The elapsed time could be four months if it is September 1 to December 31, three months if it is September 15 to December 15, or two months if it is from September 30 to December 1. Some students seem to resolve this by using the same day in each month. Others use all of both months. Still others are just stymied, not knowing what to do. A convention for this kind of problem has not been agreed upon, so we suggest that item writers give the specific

the one the student is being asked to answer.

Recommendations for Curriculum

It appears to us that much about the mathematics curriculum could be improved for the purpose of developing students' skills in solving problems of everyday life. Notice that we did not study the curricula, but on the project team were three specialists in mathematics education and one additional person with an undergraduate mathematics major. We were not without background from which to address this topic. Our recommendations will be very specific for the most part, but some will be more general.

First, it seems clear to us that some very useful strategies in solving everyday problems are not being adequately learned. They include estimation procedures and their uses, the use of approximations in place of awkward numbers in order to get ballpark figures, and the practice of determining in the beginning just what the final answer is to look like--in what units it is to be expressed.

Second, it seems to us that for many students the basic skills need to be maintained by the school's curriculum. It is not enough to develop them and then have the student forget them. For some students some of the basic skills may not even be adequately developed by the eleventh grade.

only to find they knew that they had to convert the percent to a decimal and then multiply, but they did not know why or who got the money. Many of them did not even have the concept of area, and essentially none of them understood enough to be able to convert square feet to square yards--even when they were told there were nine square feet in one square yard.

It seems to us that one of the problems in helping students to develop and polish these kinds of skills is that they are not frequently used in other school courses where they might be. Though it might be quite confusing and destructive of the meaning of grades in another course such as history if arithmetic applications had a large part in determining the grades given, there is no reason that when dates are being studied students cannot be asked to determine how long it was between events. That is what elapsed time is all about. They can be asked to decide which alternative solutions to social problems appear to cost less, in the long and the short run. That is comparison shopping. In reading and social studies students can be required to use materials that require reading of tables and graphs, and all of this need not interfere with the other subjects in any way.

Another problem seems to us to be that the use of basic skills in solving problems of everyday life is probably not introduced into the arithmetic curriculum as early as it

might be. Simple problems related to games, hobbies, trips, etc., could easily be introduced in the early grades to build the skills involved in problem solving mentioned earlier.

Some more specific suggestions include the following:

Take some kind of positive action to deal with elapsed-time problems in which it is unresolved whether one counts both beginning and end dates as part of the elapsed time, whether he counts only one, or neither. This could involve developing a general agreement among the mathematics-education community, or, alternatively, teaching the children each of the possibilities and how to decide among them. But something should be done.

Be sure students know how to deal with mixed numbers, such as 10 1/2 times 10. They do not know what to do about the 1/2. They should learn how to use it as a fraction, and how to convert it to a decimal, and how to go back and forth between the two systems efficiently.

It appears from our experience that an effective way to teach comparison shopping would be the step-by-step procedure that we used here. An example is the following:

Problem: A jar of peanuts weighs 5 ounces and costs 59¢. Another jar of peanuts weighs 10 ounces and costs 89¢. Which size jar would be the more economical buy if you needed 20 ounces of peanuts altogether?

Solution:

a. How many of the 5-ounce jars of peanuts would you buy if you needed 20 ounces of peanuts altogether?

b. How much would the 20 ounces of peanuts cost?

c. How many of the 10-ounce jars of peanuts would you buy if you needed 20 ounces of peanuts altogether?

d. How much would the 20 ounces of peanuts cost?

e. Which size jar would be the more economical buy if you needed 20 ounces of peanuts altogether?

In our limited set of data a dozen or so more students were able to solve that kind of problem after going through one step-by-step exercise than were able to solve it before that experience.

However, breaking area problems into steps does not seem so effective. The steps are different. In area, the main steps are two, a multiplication to get square feet, and then a conversion to square yards. Even when we told them that one square yard equals nine square feet, they seemed unable to use the information effectively.

The step-by-step procedure did not promise to be a sufficient procedure for teaching interest either. Nor did a sequence of graduated steps seem adequate to teach solution of elapsed-time problems that involved regrouping. However, a variety of approaches to teaching these concepts and problem-

solving methods should be developed and tried out in order to learn which are effective and which are not, much as we explored a few here.

It is interesting to note as a sidelight that the group of advanced students we tested in one urban high-school were surprisingly ineffective with some of these problems, too. These students were in a class in which a number of different topics were being taught, such as trigonometry, advanced algebra, and solid geometry, on an individualized basis. The students were definitely not having difficulty with mathematics per se. Still they were relatively unsuccessful in dealing with comparison shopping problems that asked the student to compare, with converting square feet to square yards, and at subtracting one time from another or determining elapsed time when regrouping was necessary. This is more evidence that these applications of basic skills just are not being learned even by the good students. If better performance on these kinds of problems is to be achieved, something is going to have to change in the curriculum that will make that achievement possible.

Recommendations for Remediation

Many of the suggestions for the curriculum apply, naturally, to remediation. If we were to plan a remediation program, however, we would add these ideas based on our experience:

1. Check to see if the prerequisite concepts and skills essential for understanding and solving practical problems of everyday life are adequately mastered, e.g.,

a. for Area--multiply 2 mixed numbers; know what a mixed number is.

b. for Comparison Shopping--divide decimals, especially when the dividend is smaller than the divisor and when the divisor is greater than 100.

c. for Comparison Shopping--recognize the order of size of decimals and fractions, e.g., recognize that 1/2 is more than 1/3.

d. for Elapsed Time--teach as counting-on strategy.

e. for Elapsed Time--regroup with denominative numbers, such as years, hours, months, etc.

f. for Interest--change percent to decimal and add whole number to decimal.

2. Develop comprehension of the contextual situation. We suspect that though the students can read the words and pick out the words that make sense in the paragraph, they often still don't know what the problem is. We suggest use of the following to help develop the necessary comprehension:

a. Practice restating problems in their own words correctly, perhaps without even going on to work out the solutions.

b. Use pure cloze exercises as another form of practice. Notice, we used multiple-choice cloze passages in the interest of efficiency. For practice in comprehension, we think that the pure cloze procedure in which the student must generate the correct word rather than choose it from a set of alternatives will be more effective. It is a more demanding skill.

c. Teach the students how to estimate what the answer should be and that the arithmetic details are to get a more precise answer that should be close to the estimate if all has gone well.

d. Teach the students to use approximations of awkward numbers to get a ballpark figure that can be checked by arithmetic on the awkward numbers.

e. Teach the meaning of specific concepts that are included in the objectives set by the State. For example, what is interest, what difference is there when you borrow versus when you deposit or lend, what is percent, what does "compare" mean, what is area, what is perimeter, how do you convert from one scale to another and why, how is time measured (time line), etc.

f. Teach the students to recognize the problems in various formats, and how to change from one format to another, such as vertical to horizontal. Teach them the equivalences of different wordings, such as 2 + 2 is the equivalent of add

two and two. Discuss the similarities and differences in formats so that this is no longer a problem.

g. Use step-by-step procedures to help develop thought patterns of problem solving.

h. Eradicate misleading shortcuts, tricks, uses of key words, and similar devices that attempt to circumvent the process of thinking. These devices include such things as "each" means to multiply, but they also include the device of using the size of the remainder to decide which quotient is largest, and the huckster's advice that the largest is the most economical.

i. Teach the students how to take tests effectively, including such ideas as making good, full marks on the answer sheet, trying every item, careful budgeting of testing time, what to do if your answer is not among the alternatives offered, careful checking of work, looking at options to see what kind of answer is expected, eliminating options that are impossible based on ballpark estimates, etc.

General Recommendations

In order for our recommendations for curriculum and for remediation to be implemented effectively, it will be necessary that those who teach mathematics be especially trained in the techniques of teaching the applications of mathematics to practical everyday problems. We know of no body of objective data indicating to what extent those now employed to teach mathematics in Florida's schools have this

knowledge base. It seems sound to us to recommend that those necessary objective data be obtained. If they reveal a lack of this background among Florida's teachers of mathematics, then appropriate action should be taken. It might include the provision of appropriate in-service training. It might also be necessary to modify the curriculum used in training mathematics teachers. It might even be necessary to take steps to be certain that only those properly trained be used in mathematics instruction. If the people of the State agree with our impression that a serious problem exists which is solvable by heroic action, then heroic action may be just what is required.

Summary

Due to the level of performance on the mathematics section of the Florida Functional Literacy Test in its first state-wide administration in October 1977, a small pilot study was initiated to see what could be found out about the nature of the problem and to make recommendations concerning testing, curriculum, and remediation. A team of mathematics educators and educational researchers was assembled. It proceeded by developing and evaluating hypotheses about the source of the low performance, using examination of the actual items, the item data from the state-wide administration, interviews with students as they worked problems like those on the test, and a formal group

test developed and administered by the research team.

The result of the pilot study is a series of hypotheses rejected, several considered doubtful, and several which seem to be supported by the team's experience. From those and the team's experiences in general, lists of recommendations for test construction, for curriculum, and for remediation, as well as several general recommendations concerning the instruction of mathematics, are presented. The findings can be summarized as follows:

1. It is not especially important that item material be relevant to teen-agers.

2. It is not important whether the question in a problem is asked at the beginning or the end.

3. Students can read the problems understanding the words and the paragraphs. However, they do not know how to convert what they read into an organized series of mathematical operations leading to the desired result.

4. Students do not use the alternative responses in items to assist them, nor do they effectively use estimates and approximations.

5. Students do not understand the concepts of area and interest, and do not know what it means to "compare," but they do understand the concept of elapsed time. They simply do not know how to calculate it when regrouping is necessary.

6. Students have difficulty with some of the basic arithmetic skills necessary for solving practical problems.

7. Some students try to use key words in order to avoid having to think a problem through. This is often the reason for getting a problem wrong.

8. Multiple-step problems are especially difficult for these students.

9. Carelessness accounts for many errors.

The recommendations can be summarized as:

1. Develop a convention about calculating elapsed time, or teach students the nuances, and design items for the test appropriately.

2. Write the items carefully being especially careful that wrong procedures do not lead to choice of the keyed alternative.

3. Be careful in the use of art work in the problems.

4. Improve the curricula in arithmetic and mathematics in the schools so that practical applications are taught more effectively and so that these skills and the basic arithmetic skills are maintained throughout school life. Start the instruction in applications earlier, and include practical use of mathematics in other subject matters.

5. Teach test-taking skills and thinking or problem-solving skills, not rote solutions or the use of short-cuts

and key words.

6. Conduct investigations to ascertain effective ways of teaching these practical applications.

7. Train and retrain mathematics teachers in principles and methods of teaching practical applications, and see to it that this material is taught to school children by trained mathematics teachers.

8. Try step-by-step and pure cloze procedures as remediation devices.

September 11, 1978

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Dr. Tom Denmark (Ph.D., Florida State University), Professor of Mathematics Education, Florida State University. Dr. Denmark's teaching responsibilities include: undergraduate and graduate courses in Mathematics Education and in Mathematics for elementary and secondary school teachers. Among these courses are two courses related to the teaching of remedial mathematics. Other activities include the operation of an Arithmetic Clinic for students in the primary grades; the development of a remedial mathematics program for a rural school system; and the training of paraprofessionals to work Title I and Title III Programs. He was the Associate Director and a principal investigator for Project for the Mathematical Development for Children.

Dr. Denmark is a member of the National Council of Teachers of Mathematics, the Research Council for Diagnostic Prescriptive Mathematics, and the Florida Council of Teachers of Mathematics. He is a Past President of the Florida Council of Teachers of Mathematics. He was a member of the Instructional Affairs Committee of the National Council of Teachers of Mathematics, chairman of the IAC subcommittee on Learning Disabilities of Mathematics. He was chairman of NCTM's ad hoc Study Group on Career Education. He has conducted for NCTM a national survey of teacher's opinions related to the teaching of mathematics basic skills. He was chairman of the Advisory Council of the State of Florida Mathematical Assessment and Accountability Programs; he also served as technical consultant to the prime contractor for these programs.

His publications include articles in the Mathematics Teacher, the Arithmetic Teacher, self-instructional units published by Houghton-Mifflin, and several technical reports for PMDC. He has also written an instructional guide for teachers to use in planning remedial programs related to Florida's Functional Literacy Mathematics Test.